

DSN Command System

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Modification of the currently operational DSN Command System MK III-80 in 1981 consisted of improvement of the uplink carrier frequency tuning capability to satisfy Voyager 2 requirements. Upgrading of Command System monitoring functions in the Network Operations Control Center is scheduled for 1982. DSN Command System requirements and functional design are described for the Mark IVA Network, which is planned for 1984-1985 implementation.

I. DSN Command System Mark III-80

The Mark III-80 configuration of the DSN Command System, which was described in Ref. 1, is the currently operational configuration. In early 1981 the uplink digitally controlled oscillator (DCO) hardware was modified to correct a performance anomaly, and the metric data assembly (MDA) software was modified to provide satisfactory control of the DCO for Voyager 2 uplink carrier frequency tuning. No other major modifications were required in the Command System.

The command processor assembly (CPA) software upgrade previously planned for 1981 has been rescheduled to late 1983 to coincide with the Mark IV-84 configuration implementation. Network Operations Control Center (NOCC) Command Subsystem software modifications, to provide computer-controlled prepass data transfer and validation tests and revised displays, are scheduled for mid-1982 as part of a general upgrade of the Network Operations Control Area (NOCA) to reduce operations costs.

II. DSN Command System Mark IV-85

A. Introduction

Functional requirements and functional design have been established for the Command System of the Mark IVA Network. The network functional design provides one Signal Processing Center (SPC) at each Deep Space Communications Complex (DSCC). The Ground Communications Facility (GCF) will provide communications between JPL and each SPC.

The Networks Consolidation Program (NCP) requires the Mark IVA Network to support high-apogee earth-orbital missions in addition to the deep space and planetary missions.

A simplified block diagram of the DSN Command System Mark IV-85 is shown in Fig. 1. Each of the three complexes (Goldstone, Tidbinbilla, and Madrid) will have a 64-meter antenna with deep space uplink, a 34-meter antenna with both deep space and earth orbiter uplinks, and a 9-meter antenna

with earth orbiter uplink. (Each complex will also have additional 34-meter antennas, for downlink only.)

B. Implementation Schedule

The Mark IVA Network implementation plan calls for an interim configuration to be installed at all three complexes in early 1984, a final configuration at Goldstone by February 1985, and at Tidbinbilla and Madrid by August 1985. The interim configuration will include new command equipment for 34-meter antenna support of high earth orbit and deep space missions, while retaining portions of the present Mark III configuration. The final configuration at each complex will include the 9-meter antenna and associated front end equipment, a total of four strings of DSCC command subsystem equipment, and the new DSCC Monitor and Control Subsystem, as shown in Fig. 1.

C. Mission Set

The Mark IVA Network baseline design is required to provide capabilities to support the flight missions listed below:

- (1) Current deep space missions:
 - (a) Pioneer 6 through 12
 - (b) Viking Lander
 - (c) Helios
 - (d) Voyager 1 and 2
- (2) Planned deep space missions:
 - (a) Galileo
 - (b) International Solar Polar Mission (ISPM); 2 spacecraft
- (3) Current high elliptical earth orbital missions:
 - (a) International Sun-Earth Explorer No. 3 (ISEE-3)
- (4) Future high elliptical earth orbital missions:
 - (a) Active Magnetospheric Particle Tracing Explorer (AMPTE); 3 spacecraft
 - (b) Origin of the Plasma in the Earth's Neighborhood (OPEN); 4 spacecraft

D. Performance Requirements

Support of the Mark IVA mission set will require Command System performance characteristics compatible with the NASA standard transponder to be used on future spacecraft and also compatible with current in-flight spacecraft and certain planned spacecraft that do not use the standard transponder. Some of the required capabilities are listed below:

- (1) Data rates. Data rates from 1 bit/sec to 2000 bits/sec will be provided.
- (2) Subcarrier frequencies. Sine wave and square wave subcarriers will be generated at frequencies of 100 Hz to 16 kHz.
- (3) Subcarrier data modulation. Selection will be provided for phase-shift-keyed (PSK) or frequency-shift-keyed (FSK) modulation of the subcarrier by the pulse-code-modulated (PCM) command symbol stream. An option for amplitude modulation (AM) of the FSK subcarrier will also be provided.
- (4) Carrier modulation. The command-modulated subcarrier will be phase-modulated on an S-band carrier for radiation to the spacecraft. Control of modulation index angle will be provided over a range from 0.1 to 1.8 radians.
- (5) Carrier frequencies. Generation of the uplink carrier at S-band frequencies assigned for deep space missions will be provided at the 64-meter and 34-meter antennas. S-band frequencies assigned for earth orbit missions will be provided at the 34-meter and 9-meter antennas.

III. System Functional Description

As discussed in Ref. 2, many of the spacecraft supported by the DSN have onboard storage and sequencing capabilities that permit command sequences to be sent well in advance of the actions to be taken by the spacecraft. Thus, fewer direct-action (real-time) commands are needed. Ground system capabilities providing massive storage of spacecraft commands, multimission operating functions, and standardized protocol were incorporated in the DSN Command System in 1978 (Ref. 3). These capabilities will be continued in the Mark IV-85 system configuration.

A. Operational Functions

End-to-end spacecraft command operations are represented functionally in Fig. 2. Command sequences for one or more spacecraft are generated and stored at a Mission Operations Center (MOC). Commands for a particular spacecraft are selected from the command files, formatted into messages, and stored for transmittal to a specified link of a DSCC. Command data are extracted from the message received and are stored until radiated. Finally, the commands arrive at the spacecraft and are either executed immediately, or stored onboard for later execution.

The functions of the DSN Command System in this process include the following:

- (1) Establishing the DSCC configuration for the specified spacecraft.

- (2) Receiving and storing command data at the DSCC.
- (3) Queuing command data to be radiated to the spacecraft.
- (4) Radiating the command data to the spacecraft.
- (5) Monitoring and reporting system status and events.

B. Operational Procedure

On-site configuration inputs to the DSCC Command (DCD) Subsystem specify the flight project name and the spacecraft identification number. These inputs cause the Command Processor Assembly (CPA) software to transfer a specified configuration and standards and limits table from disk storage to memory, and to configure the DCD Subsystem according to the table. Changes may later be made by high-speed data messages from NOCC (or by keyboard entries at the Link Monitor and Control Console).

Prior to the beginning of the scheduled spacecraft track, the control of the DSCC command functions is transferred to the NOCC. Configuration standards and alarm/abort limits are updated by transmission of high-speed data messages from the NOCC Command Subsystem (NCD) real-time monitor processor. The standards and limits are derived from files maintained in the NOCC Support Subsystem. Spacecraft-dependent parameters, such as symbol period, subcarrier frequency, alarm limits, and abort limits, are established via these messages. After the proper configuration standards and limits have been established, test commands are transmitted through the system to ensure that the system can accept spacecraft commands via high-speed data messages, temporarily store the commands, and confirm radiation. After the network operations control team has established that the system is operating properly, the system control is transferred to the flight project's MOC for loading of actual spacecraft command sequences to be radiated to the spacecraft during the track period.

At the time for radiation of each command element, the subsystem advances to the active mode (see Fig. 3 for description of the various modes) and command data are transferred to the Command Modulator Assembly (CMA) for immediate radiation via the Receiver-Exciter, Transmitter, Microwave, and Antenna Subsystems.

C. Command Data Handling

The DCD Subsystem design allows mission operations to prepare large files of spacecraft commands in advance and then to forward several files to the DSCC link at the beginning of a spacecraft track.

1. Command files. Each file may consist of up to 256 high-speed data blocks. The content of each data block is a file

element. The first block in a file contains the *header element* and each remaining block contains a *command element*. Each command element may consist of up to 800 bits of spacecraft command data. Up to 8 files for a given mission can be stored by the CPA. Thus, the available storage is over 1.6 million command bits.

The header element contains file identification information, file processing instructions, and a file checksum. The file processing instructions include optional file radiation *open* and *close window times*, and an optional *file bit 1 radiation time*. File open and close window times specify the time interval during which command elements in the file may begin radiation (i.e., a mission sequence may demand that specific commands not be sent before or after a certain time). The bit 1 radiation time allows the project to specify the exact time at which the file is to begin radiation to the spacecraft. The file checksum provides end-to-end error protection for the ground command system. It is created at the time of file generation and is passed intact to the DSS. It adds reliability to insure that no data were dropped or altered in the transfer from one facility to another.

The command elements each contain command bits, file identification, element number, element size, and an optional "delay time" (interval from start of previous element). If delay time is not specified, the element will start radiating immediately after the end of the previous element.

2. Receiving and storing command data at a DSCC. Normally, the files of commands to be radiated to the spacecraft will be sent from the MOC to the specified DSCC link at the beginning of a spacecraft track period. However, files may be sent to the DSCC link at any time during the spacecraft track period. The first step in receiving and storing command data at a DSCC is the process of opening a file area on the CPA disk. The MOC accomplishes this by sending a header element, which serves as a *file-open* directive. After the CPA acknowledges receipt of the header element, the MOC sends the remainder of the file (up to 255 command elements) and follows it with a *file-close* directive. The CPA acknowledges the file-close instruction and indicates whether the file loading was successful or unsuccessful. If the file loading was unsuccessful, the acknowledge message contains the reason for the failure and from what point in the file the command elements are to be retransmitted. When the file is successfully closed, the MOC may proceed to send additional files, up to a total of eight.

3. Queuing the command data for radiation. After the files are stored at the CPA, the MOC sends one or more *file-attach* directives to place up to five file names in the radiation *queue*. The Mission Control Team determines in which order the files

are to be attached. The order in which they are attached determines the sequence in which they will be radiated: that is, first attached, first to radiate to the spacecraft.

4. Command radiation to the spacecraft. The first command element in the top (prime) file in the queue begins radiation to the spacecraft immediately after attachment or as soon as all optional file instructions (such as bit 1 radiation time) are satisfied. The prime file status is defined to be *active* when the first command element begins radiation. Upon completion of radiation of the first command element, the second command element begins radiation either immediately or when the optional delay time has been satisfied. The process continues until all command elements in the file have been radiated. After the first file completes radiation, the second file in the queue automatically becomes the prime file and the command radiation process is repeated. After the second file completes radiation, the third file becomes prime, etc. This process is repeated until all files in the queue are exhausted. The MOC can attach new files to the queue whenever space is available.

Confirmations of command element radiation are reported in *event messages* to the MOC and NOCC once per minute, or after five elements have been radiated, whichever occurs first. If a command element is aborted, or if an alarm occurs, an event message is sent immediately.

5. Additional data processing. The foregoing descriptions of the DSCC functions of storing the command files, attaching the files to the queue, and radiating the commands to the spacecraft assume nominal-standard operation. Additional data processing functions are provided for worst-case conditions, nonnominal operations, and failure recovery. Control of these functions is normally exercised remotely from the MOC. However, emergency control is also available at the Link Monitor and Control Console.

a. File erase. A file can be deleted from storage at the CPA by means of a *file erase* directive, if the file is not attached to the radiation queue.

b. Clearing the queue. As previously stated, the order of file radiation to the spacecraft is dependent on the order of files in the queue. To rearrange the order, a *clear-queue* directive must be sent, followed by file-attach directives in the desired order.

c. Suspend radiation. If the Mission Control Team desires to stop command radiation, a *suspend* message can be sent to the CPA. This message stops command radiation to the spacecraft upon completion of the current element. The file status then changes from active to suspended.

d. Resume command radiation. To restart radiation of a suspended file (either suspended intentionally or from an abort), a message can be sent to *resume* radiation at a specified unradiated element in the file. The suspend and resume-at directives can be used for skipping elements of the prime file, if desired.

e. Command abort. As each command bit is radiated to the spacecraft, numerous checks are made to insure validity of the command data. If a failure is detected during the radiation, the command element is automatically aborted, the prime file status is changed from active to suspended, and radiation is terminated until a resume directive is received.

In addition to the automatic abort function there is provision for the MOC to send an *abort and suspend* directive to terminate command radiation immediately without waiting for completion of an element.

f. Close window time override. If a close-window time is specified in a file header element, and the Mission Operations Team later decides to extend the permissible time for radiation of that file, an *override* message can be sent (after the file becomes prime) which instructs the CPA to ignore the close-window time.

D. Data Records

All high-speed data blocks received by the CPA and all blocks sent from the CPA are to be logged at the DSCC on the Original Data Record (ODR). In addition, the CPA has the capability to record a temporary ODR on disk if the ODR is disabled.

High-speed data blocks from all complexes are recorded at the GCF central communications terminal (CCT). Command system high-speed data blocks from a Mission Operation Center to a DSCC are also recorded at the CCT.

The DSCC original data records and the CCT recording provide information for fault isolation in case problems occur in the Command System operation.

IV. Subsystems Configurations for Mark IV-85 System

Planned modifications and reconfiguration of subsystems for the DSN Command System Mark IV-85 (and Mark IV-84) are summarized below.

A. Antenna Mechanical Subsystem

At Tidbinbilla and Madrid all antennas will be located in the vicinity of the SPC. At Goldstone, the 64-meter antenna

and the 9-meter antenna will be located near the SPC. The Goldstone 34-meter transmit-receive antenna will remain at the present DSS 12 (Echo Station) site, but control will reside at the SPC.

B. Antenna Microwave Subsystem

For the 9-meter antenna, the microwave subsystem will provide uplink signal feed at S-band frequencies assigned for earth orbital missions (2025-2110 MHz). For one 34-meter antenna at each complex, the microwave subsystem will be required to handle S-band uplinks over the range of earth orbital and deep space missions (2025-2120 MHz). For the 64-meter antenna the microwave subsystem uplink capability will be unchanged (S-band 2110-2120 MHz).

The 9-meter and 34-meter antenna microwave subsystems provide selection of right or left circular polarization. The 64-meter antenna microwave subsystem provides selection of linear polarization or right or left circular polarization.

C. Transmitter Subsystem

The 9-meter antenna will have a 10-kW transmitter operating in the earth orbital mission S-band frequency range. A 34-meter antenna will have a 20-kW transmitter operating over the range of earth orbital and deep space mission S-band frequencies. The 64-meter antenna will have 20-kW and 100-kW transmitters for the deep space mission S-band frequency range, as now.

D. Receiver-Exciter Subsystem

An S-band exciter will be acquired with each 9-meter antenna from the Ground Spaceflight Tracking and Data Network (GSTDN). The DSN exciter for the 34-meter antenna will be upgraded to cover earth orbital and deep space mission S-band frequencies. The present DSN S-band exciter will be retained in the 64-meter antenna link.

Functions of the exciter include receiving the command-modulated subcarrier signal from the DSCC Command (DCD) Subsystem, phase-modulating that signal on the uplink carrier, returning a demodulated signal to the DCD subsystem for confirmation, and sending modulation on or off indications to the DCD subsystem.

E. DSCC Command Subsystem

In the final Mark IVA Network configuration (in 1985), the DCD Subsystem in the SPC at each complex will be implemented as shown in Fig. 1. A new Command Switch Assembly (CSA) will permit any of three exciters to be connected to any of four Command Modulator Assemblies (CMA) under control of the Complex Monitor and Control console.

New CMA's will be implemented to accommodate the Mark IVA mission support requirements. The Command Processor Assemblies (CPA) will use existing Modcomp II-25 computers with core memory increased to maximum capacity. CPA software will be upgraded to satisfy new mission support requirements, to modify the CMA interface functions, and to provide required functions for interfacing with the new DSCC Monitor and Control Subsystems.

For the interim configuration (in 1984), two of the new CMA's (one prime, one backup) will be provided at each complex, to provide required command capability for the 34-meter antenna subnetwork. An interim software program will be implemented in the CPA to operate with the new CMA.

F. DSCC Monitor and Control Subsystem

New equipment will be implemented for the DSCC Monitor and Control (DMC) Subsystem at each complex in the final Mark IVA Network configuration. Assignment of command equipment (antenna, transmitter, exciter, and command modulator-processor combinations) to a given "link," for each scheduled spacecraft pass or for a scheduled test, will be accomplished by the DMC Subsystem along with telemetry and tracking equipment assignments. Prepass countdown will be controlled by inputs at the Link Monitor and Control Console.

The DMC Subsystem will receive antenna pointing and uplink frequency predictions and will relay them to the appropriate subsystems. The DMC Subsystem will send link status information to the CPA, and the CPA will send Command Subsystem status information to the DMC Subsystem for link console displays and for incorporation into the monitor data that the DMC Subsystem sends to the NOCC.

In the interim configuration, the Monitor and Control Subsystem will be limited to the existing Data System Terminal (DST) and Digital Information Subsystem (DIS) functions.

G. GCF Subsystems

In the final Mark IVA Network configuration, the GCF Digital Communication (GDC) Subsystem will replace the present GCF High Speed and GCF Wideband Subsystems. All command data blocks will be communicated at a line rate of 56 kb/s, instead of the present 7.2 kb/s rate, between the Central Communications Terminal at JPL and the Area of Routing Assembly at each DSCC.

At the Goldstone DSCC the GCF Intersite Communication Subsystem will communicate the CMA output signal from the

SPC to the DSS 12 exciter and the confirmation signal from the exciter to the SPC.

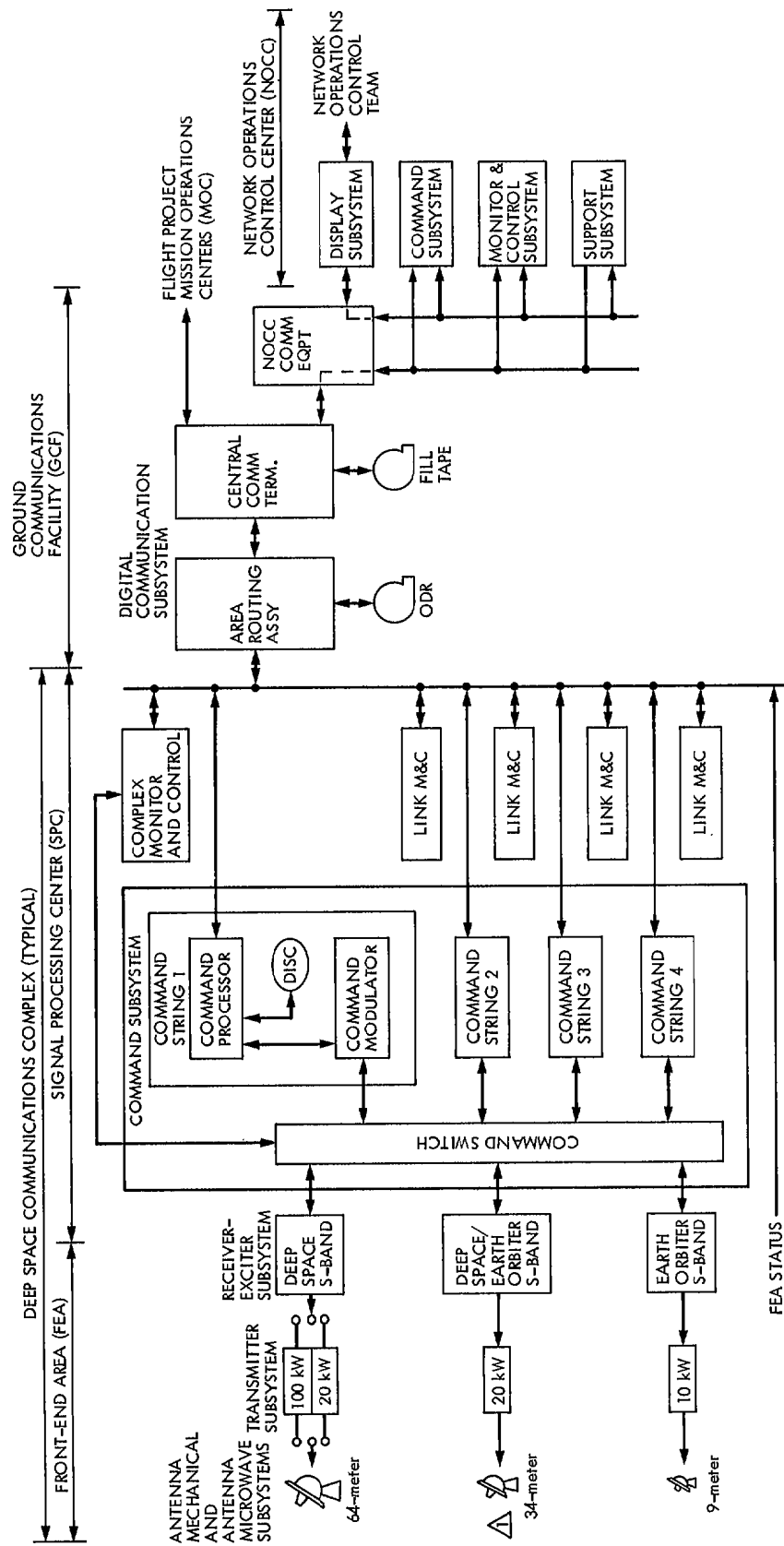
H. NOCC Command Subsystem

The NOCC Command (NCD) Subsystem Real-Time Monitor (RTM) software will be upgraded to accommodate new

destination codes, spacecraft identifiers, standards and limits tables and test command tables for the interim and final configurations. The NOCC Support Subsystem will be expanded to provide capability for command system performance records and analysis and additional capacity for test command tables.

References

1. Thorman, H. C., "DSN Command System Mark III-80," in *The Telecommunications and Data Acquisition Progress Report 42-57*, pp. 35-42, Jet Propulsion Laboratory, Pasadena, California, June 15, 1980.
2. Stinnett, W. G., "DSN Command System Mark III-78," in *The Deep Space Network Progress Report 42-43*, pp. 4-8, Jet Propulsion Laboratory, Pasadena, California, February 15, 1978.
3. Thorman, H. C., "DSN Command System Mark III-78," in *The Deep Space Network Progress Report 42-49*, pp. 11-18, Jet Propulsion Laboratory, Pasadena, California, February 15, 1979.



NOTE Δ AT GOLDSTONE DSCC THE SIGNALS TO/FROM FEA 12 FROM/TO SPC 10
COMMAND SWITCH ARE VIA GCF INTERSITE COMMUNICATION

Fig. 1. DSN Command System Mark IV-85 block diagram

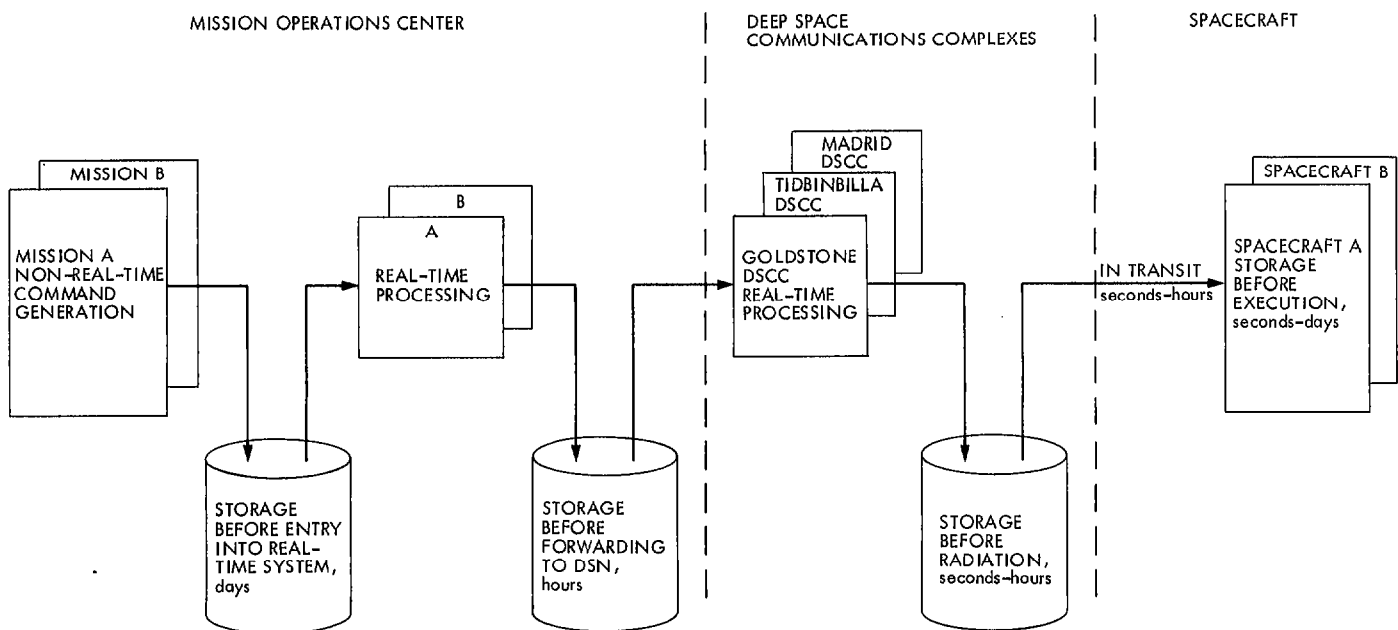


Fig. 2. End-to-end command data flow – typical storage times

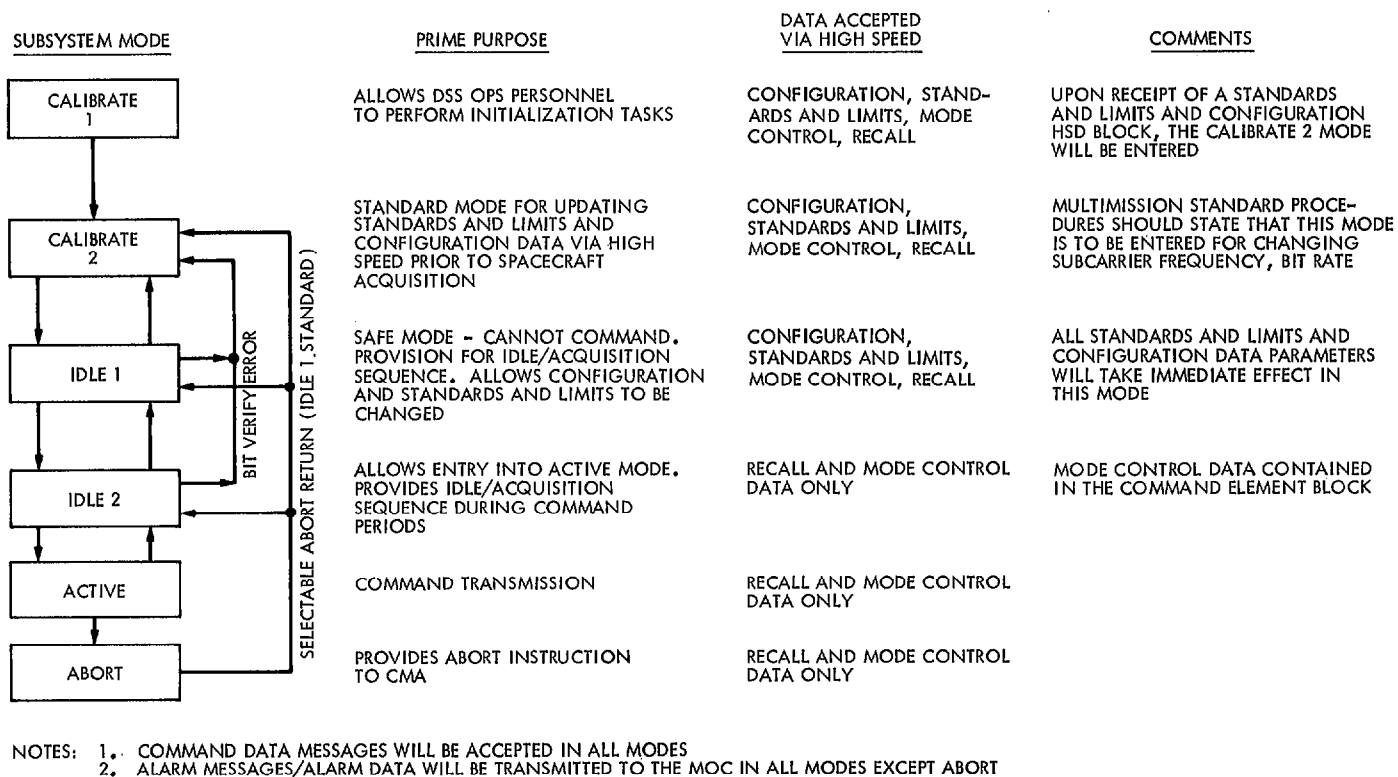


Fig. 3. DSCC Command Subsystem modes